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VISUAL AND KINESTHETIC SHORT-TERM MEMORY OF A CONSTANT WEIGHT LOAD

by

© M.J. HUGHES

A THESIS
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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "Visual and Kinesthetic Short-Term Memory of a Constant Weight Load" submitted by M.J. Hughes in partial fulfilment of the requirements for the degree of Master of Science.

ABSTRACT

The purpose of the study was to investigate visual and kinesthetic short-term memory of a constant weight load.

Nine male right dominant students from the P.E. 218 class of the University of Alberta were chosen as subjects. Subjects were tested on a replacement accuracy task.

The task required the subjects to rotate a handle in a clockwise direction until signalled to stop. Subjects removed their hands from the handle and the experimenter randomly repositioned it. Subjects were then asked to return the handle to the position in which they had left it. The difference between their first setting and their recall setting was measured in degrees. This error was the dependent variable.

Each trial was performed under one of eighteen experimental conditions. These conditions comprised two conditions of sensory modality, three conditions of short-term memory and three conditions of constant weight load. Each subject repeated the experiment on four separate occasions.

Raw data was collated and submitted to three way and five way analyses of variance. Significant F ratios were analysed by the Duncan's New Multiple Range Test.

Significant F ratios were obtained ($p < .01$) for the sensory

modality and short-term memory factors. No significant value was obtained for the constant weight load factor.

On the basis of this study the following conclusions were reached:

1. There is no significant difference in replacement accuracy for the immediate recall and delayed recall conditions of short-term memory. But both these conditions are significantly better than the delayed recall plus interpolated task condition.

2. For each condition of short-term memory replacement accuracy for the visual modality is significantly better than for the kinesthetic modality.

3. There is no significant difference in replacement accuracy for the three levels of constant weight load.

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CHAPTER I

STATEMENT OF THE PROBLEM

Introduction

An understanding of how complex patterns of behaviour are organized and controlled would be an advantage in the study of perceptual-motor skills. Investigation into the area based on a study of motor skills isolated from associated sensory mechanisms does not appear to have supplied this understanding. Fitts (19:224) claims that what is necessary in the analysis of behaviour is an approach involving the entire receptor - neural - effector system.

This approach would take into account the information the performer is using as the basis for his behaviour. Controlling the information available to the performer would enable data on its value to him to be obtained from his response. A change in the amount of information available could be effected by changing, along one dimension, the stimulus level. Comparisons between responses obtained at various stimulus levels may aid an assessment of the value of the stimulus to performance.

The variation in the level of information need not be large but would need to be greater than a just noticeable difference for that type of stimulus. If that stimulus is being used by the performer

to aid response in a replacement task, variations in the level of the stimulus should produce variations in the accuracy of the response.

Responses are not made on the basis of current information input alone. Information retrieved from memory also aids the performer to choose appropriate response (12). Broadbent's (8) model of information-flow in the human organism first postulated the notion of a short-term memory system as a separate construct, with properties distinct from those of long-term memory. The concept appears to be justified by experiments demonstrating that much information available to a performer is not retained for more than a brief interval (21:24). The important distinction to be made between short-term memory and long-term memory is that in short-term memory information is lost rapidly in the absence of sustained attention whereas in long-term memory information is relatively fixed and does not require constant rehearsal. Information may pass from short-term memory to long-term memory by rehearsal, although such factors as the novelty of the stimulus and the number of repetitions of that stimulus are also factors in how quickly and effectively information becomes fixed in long-term memory (19:68).

The concept of a short-term memory system has important implications for the analysis of skilled motor performance (19:245). In many situations the performer is required to take cognizance of a multitude of sensory stimuli. Of these not all will be relevant to his task. He must discriminate between those that are relevant and

those that may be discarded, between those requiring immediate response and those that need to be stored until the appropriate response is required. But just how the decay of information from short-term memory affects performance of a perceptual-motor skill is not fully understood, nor is the influence of an interpolated task. Information on these two points could be of assistance in aiding perceptual-motor performance.

Sperling (33), using visual stimuli, demonstrated the existence of a system which preserves information prior to its being processed, called the sensory storage system. Broadbent (8) using auditory stimuli and Adams and Dijkstra (2) using kinesthetic stimuli obtained results which led them to support the concept of a sensory storage system. Such a system appears to be needed by the model to explain man's ability to report information arriving at unattended channels.

Even so not all experimental results can be adequately explained in terms of the model. Posner (27), for example, working with kinesthetic cues has shown that at the limits of short-term memory (one minute by his definition), kinesthetically stored information can be recalled more accurately than visually stored information. In another study Posner (31:29) investigated the effect of an interpolated task on information stored by different sensory modalities. The results he obtained led him to conclude that kinesthetically stored information is not affected as seriously by an interpolated task as is visually stored information.

The results of these studies suggest that the storage of information by the visual and kinesthetic sensory modalities does not follow the same pattern. Adams and Dijkstra (2) suggest there may be more than one sensory storage system. The lack of studies related to the storage of information by the visual and kinesthetic sensory modalities suggests that further studies in this area would be of value. The inability of researchers to offer explanations for the results of studies done, further suggests that much more data as to the nature of kinesthetic and visual storage of information is needed.

The Problem

1. To determine the nature and the extent of the relationship between the visual and kinesthetic sensory modalities and three conditions of short-term memory using a replacement accuracy task.

2. To determine whether a constant weight load, administered at three levels, for a replacement accuracy task has any effect on performance of the task under the conditions of short-term memory and sensory input as noted in paragraph one.

Limitations

The study used a handle turning task to measure replacement accuracy. An assumption made is that this task is an appropriate vehicle for testing the sensory modalities and short-term memory factors it purports to measure.

The study is limited by the accuracy of the apparatus, particularly the recording scale.

A further limitation is the accuracy of the experimenter in reading and recording the scale measurements. Recordings will be made to the nearest degree.

Delimitations

The study is confined to nine male students of the University of Alberta.

Definitions

For each trial subjects turn the handle until signalled to stop. The handle is then randomly repositioned by the experimenter, the weights removed and the appropriate short-term memory condition invoked. Subjects are then required to recall as accurately as possible the previous position of the handle. This task is defined as the *replacement accuracy task*.

Short-term memory is defined as a system which loses information rapidly in the absence of sustained attention.

Interpolated task is defined as an unrelated task which the subject is required to perform during the interval between the trial and the recall.

For the purposes of this study *immediate recall* is defined as a recall within a period not exceeding three seconds.

Hypotheses

The following hypotheses were investigated:

1. (a) Visually stored information is recalled more accurately than is kinesthetically stored information for the immediate recall and delayed recall conditions of short-term memory.

(b) Kinesthetically stored information is recalled more accurately than visually stored information for the delayed recall plus interpolated task conditions of short-term memory.

2. (a) There is no significant difference in the replacement accuracy for the immediate recall condition and the delayed recall condition.

(b) Greater errors in replacement accuracy occur for the delayed recall plus interpolated task condition than for either the immediate recall condition or the delayed recall condition of short-term memory.

3. No significant difference in replacement accuracy occurs for the three weight conditions.

CHAPTER II

REVIEW OF THE LITERATURE

Visual and Verbal Short-Term Retention

Problems relating to the storage and recall of visual information, and kinesthetic information are basic to the analysis of skilled performance (8:241). Studies on the short-term memory of verbal material are discussed here because they indicate some limits placed on human performance by this construct.

Conrad and Hille (11) in a study on the recall of an eight digit message varied the time in which the digits were kept in memory by altering the rate of presentation and the rate of recall. They concluded from their results that in the absence of rehearsal, accuracy of recall falls rapidly over time.

Murdock (20) in a similar study obtained similar results. He found that the number of items retained after one presentation was a linear function of the time taken to present the list. The length of time taken to present the list was dependent upon the length of the list and the rate of presentation of the items.

Posner (28) points out that the rate of presentation of items:

(1) changes the time the item must stay in store prior to recall and,

(2) alters the time available for rehearsal, association or the use of other strategies to aid recall.

He used two speeds of presentation, namely, 30 or 96 digits per minute. By controlling the order of recall of items he concluded that better results were obtained from the faster speed of presentation.

The studies so far mentioned controlled the effects of rehearsal upon results. Sanders (32) investigated the effect of rehearsal on retention and recall of verbal items. He hypothesized that the best type of rehearsal is by means of interpretation and association. The results of his experiment led him to conclude that repetition is also of considerable value as an aid to recall.

Mackworth (16) in her study using visual presentation of digit messages found that reducing the rate of presentation improved recall accuracy. She used presentation rates of 2, 1-1/2, 1, 1/2, and 1/4 seconds per item. She suggested that the improved results with slower presentations may have been due to the fact that it gave subjects time to rehearse the items during the presentation.

Pollack, Johnson and Knaff (26) also found a decrease in recall accuracy as the speed of presentation increased. Their experiment used messages of known and unknown length. Both types of messages were adversely affected although the messages of known length suffered comparatively more interference.

Pillsburg and Sylvester (25) studied retention over a 10 second interval. They found a reduction in recall of various types of visual materials after intervals of less than 10 seconds.

Anderson (3) in a similar study tested recall and found a decrease over time. He claimed that most forgetting occurs in the first 5 seconds after presentation of the stimulus.

McLane and Hoag (22), using visual stimuli and testing recall over time obtained results differing from the studies so far mentioned. The graph of their results for the 3 minutes after presentation shows a series of peaks and depressions. The curve after 3 minutes is still rising and is at a higher point than at immediate recall. The highest point for retention on the graph occurred after an interval of 20 seconds.

<u>Interpolated Tasks</u>

Peterson and Peterson (24) in a study using single verbal items as the stimuli concluded from their results that there was progressive forgetting over time. In this experiment the subjects were required to count backwards by threes or fours for various delays between the presentation of the stimulus and the signal for recall. The experiment also investigated the results of rehearsal upon recall. They concluded rehearsal assisted recall and that the rate of forgetting varied inversely with the amount of rehearsal.

Murdock (21) claims his study supports and extends that of Peterson and Peterson. He obtained results similar to theirs using a similar stimulus and interpolated task. In addition he tested the effect of varying the amount of information contained in the interpo-

lated task. His conclusion was that it is the amount of information in the interpolated task and not the rate of its presentation, which is the critical factor in causing interference.

Brown (9) also experimented with delay and interpolated tasks. He claims that for even very brief delays the interpolation of a single stimulus between the end of the message and its recall leads to memory loss. When the information content of the interpolated task is increased the amount of forgetting increases accordingly. But if subjects were given time to rehearse the message before the interpolated stimulus was given, less interference took place.

Conrad (10) further tested this problem using messages consisting of 7 or 8 digits. But subjects were required to prefix their recall response with a zero. The interpolation of this single digit before recall led to a substantial memory loss even though the nature of the interpolated task was known in advance. Results of other aspects of this experiment were not in agreement with those obtained by Brown. Conrad gave subjects a 10 second delay before introducing the interpolated task and urged them to rehearse the message during the interval. No improvement in performance resulted.

Mackworth (17) required subjects in the recall condition to select manually the correct response from a display of possible responses. The experimental group gave considerably fewer correct responses for this task, compared with the group who were not required to make the selection. She suggested that the task of selection is

itself an interference with the memory and is responsible for the increased forgetting.

Aborn and Rubenstein (1) in their study investigated the relationship between information in the message and accuracy of recall. Their results led them to conclude that up to a certain degree of complexity the amount of information learned was constant. As the complexity of the message increased the amount of information recalled increased, but the increase was in an inverse proportion to the amount of increase in the message.

Posner and Rossman (31) stressed three factors in relation to recall and interpolated tasks. They identified the following crucial factors in the recall of information:

(1) the similarity of the interpolated task to the message,

(2) the length of time which the interpolated event interrupts rehearsal of stored information and,

(3) the amount of information in the interpolated tasks.

Kinesthetic Short-Term Memory

Weber (34) was one of the first to experiment with the kinesthetic input of information. His experiment investigated two aspects of this modality:

(1) the reproduction of distances under a given load or weight,

(2) the reproduction of time intervals.

The equipment required the subjects to move a carriage along

a horizontal bar in an effort to reproduce a distance previously practiced, or to move it for a period of time previously practiced. The conditions could be changed by the addition of weights to the carriage. Weber obtained results which gave systematic errors proportional to the weight used. For increasing weights, subjects tended to reproduce distances increasingly shorter than the standard. Similarly for increasing weights, subjects tended to reproduce time intervals increasingly less than the standard. Weber concluded from these results that subjects use position and rate cues to measure duration rather than rate or time to measure position.

Ellis, Schmidt and Wade (14) obtained experimental evidence supporting Weber's findings. They concluded that weight assisted the accuracy of a timed movement. They hypothesized that increased weight gives increased information to the subject which in turn aids response accuracy.

Day and Singer (13) using similar apparatus claimed to have obtained evidence relating to the source of kinesthetic stimuli. Their results led them to conclude that kinesthetic feedback is not related to muscles or muscular activity involved in a movement. They suggested kinesthetic feedback is related to the relative position of the joints.

The experiment by Day and Singer involved kinesthetic spatial after effect and in this respect included a parameter not involved in Weber's experiment. Despite this, it is apparent that there is a serious conflict between them with regard to the source of kinesthetic information.

A study by Henry (15) required subjects to maintain the position of a lever which was subjected to constantly varying pressure to disrupt it from its original position. A graphic record of subjects' responses was obtained. Interpretation of the graph indicated that subjects were able to maintain the position of the lever with a high degree of accuracy. This remained true even when the external forces to change the position of the lever were below the threshold of perception.

Bahrick, Bennett and Fitts (4) used a spring loading device to investigate accuracy of lever positioning responses. They concluded that the forces opposing the movement of the lever provided useful cues in learning to execute different amplitudes of movement; also that the usefulness of this information depends upon the relative and absolute torque changes per unit of control motion.

In a similar experiment Bahrick, Fitts and Schneider (5) added a damping device to the lever. The purpose of the device was to alter the force required in setting the lever position at the prescribed rate of movement. Results led the experimenters to conclude that subjects achieved a greater degree of accuracy in the movement task when the damping device operated, due to increased discrimination induced by the damping mechanism.

Battig (6) in a lever positioning study investigated the relative efficiency of the various methods of sensory input and practice conditions. Best results were obtained from subjects who had received

practice with both visual and kinesthetic cues. The subjects who had received practice with kinesthetic cues only showed improved performance, but were inferior in performance to the group using visual and kinesthetic cues.

A study of short-term memory of position and force was conducted by Norrie (23). She reported that any change in force a subject exerted in a response was not significant over a 4 minute interval. A feature of this experiment was that subjects consistently over-estimated the standard force when tested on immediate recall. Norrie suggested that kinesthetic spatial after-effect may have been the cause of this error.

A study of Bilodeau, Sulzer and Levy (7) on a lever positioning task showed evidence of forgetting similar to that for verbal items. The conditions used were immediate recall and delayed recall. The period of delay was 28 days. Both conditions produced errors in recall although there was a much higher error rate for the 28 day delay condition.

The results of a study by Adams and Dijkstra (2) led them to conclude that motor responses show rapid forgetting over time, as do verbal responses. Their study involved the reproduction of given distances following delays of from 5 to 120 seconds. They also tested reinforcing trials as a method of minimizing recall errors. They concluded their study be asserting that accuracy for perceptual motor responses is a decreasing function of time and an increasing function

of the number of reinforcements. They claim their data supports the view that verbal and non verbal data follow the same general laws in respect of short-term memory. One reservation they acknowledge with respect to this claim is that their motor task may have involved a substantial verbal component.

Broadbent (8:241) hypothesized that there was a difference between perceptual motor skills and verbal skills in relation to their demands on the central processing capacity. He attributed this to the fact that there is less conscious rehearsal in bodily skills than in verbal learning involving sequences of stimuli.

Visual and Kinesthetic Information in Perceptual Motor Skills

Posner and Konick (30) used Broadbent's hypothesis in an experiment testing the accuracy of visual location and kinesthetic judgement of distance. In one experiment subjects were required to recall the position of a circle 1/4 inch in diameter situated at one of twelve positions along a horizontal line. The sensory input available for the stimulus involved both visual and kinesthetic channels. The interpolated task conditions used involved four different operations with a set of numbers. Results led them to the conclusion that as the interpolated task difficulty increased retention decreased. The amount of forgetting is not consistent with each task. Results for the "Rest" condition showed the least forgetting. The amount of forgetting was fairly constant for the first 20 seconds. By contrast the results for

conditions having more complex interpolated tasks show a fairly constant and rapid curve of forgetting.

In a second experiment only kinesthetic input was available to subjects. The task required them to replicate a given distance by moving a lever. The same four conditions of interpolated tasks were used. All conditions showed forgetting over the 30 second interval but this was unrelated to the difficulty of the interpolated task. Posner and Konick suggested that retention of the information was through imagery rather than verbal codes. They concluded that their experiments provided evidence supporting Broadbent's hypothesis that information about of the nature of visual location requires the attention of the central processing capacity but information of the nature of kinesthetic location does not.

From the results they also concluded that when both visual and kinesthetic sensory input was available, subjects relied on visual input only. This finding has implications for all studies which compare results using visual and kinesthetic sources and information input.

Mei-Fang Chang (18) investigated the relationship between tactile kinesthetic judgement and visual judgement of distance. He concluded from his study that there was no evidence to support the view that tactile kinesthetic space perception is derived from or calibrated in terms of visual space perception. He suggested rather that his evidence supported the view that the two modalities are independent.

An extension of the Posner and Konick study was undertaken by

Posner (28). His purpose was to investigate whether the visual location task would show no forgetting at rest and increased forgetting with an interpolated task. For the kinesthetic location task the study was to investigate whether the task would show forgetting at rest but no increased forgetting after an interpolated task.

From the results Posner concluded that for the visual task forgetting is greatly increased by the interpolated activity but that for the kinesthetic task forgetting is not increased significantly by an interpolated activity. He suggested that interpolated tasks act primarily to control the central processing capacity of the subject during the interval. This capacity is apparently of little consequence to information stored from kinesthetic sources.

Wilberg (36) conducted an experiment using input of information from kinesthetic and visual sources. The task required subjects to twist a handle against a constant pressure measured in pound-inches of torque. The assumption underlying the use of torque as a source of information was that it was a readily available form of information in many motor tasks. The short-term memory conditions used in the experiment were immediate recall, delayed recall, and delayed recall plus interpolated task. The results of the experiment led Wilberg to conclude that torque was not a factor aiding subjects on a replacement accuracy task. Other conclusions reached were that there was a slightly better level of performance using the visual modality and also that a large drop in performance accuracy occurred for the interpolated task condition.

CHAPTER III

METHODS AND PROCEDURES

Sample

The subjects were nine male students of the University of Alberta chosen from volunteers registered in the P.E. 218 service program. The only condition imposed on the selection of subjects were that they be right dominant and not suffering from any obvious physical disabilities limiting their capacity to perform the necessary tasks.

Task

The subjects were required to rotate a handle in a clockwise direction until signalled to stop. Within three seconds of the stop signal, the subjects were given a verbal command indicating the experimental condition to be used for the trial. During a delay period interpolated between the initial handle rotation and recall the handle was randomly repositioned by the experimenter. Following the interpolated delay period the verbal command, "Recall"! was given. On hearing this command the subjects were required to reset the handle as close as possible to the position in which they had left it.

Independent Variables

Three factors were chosen as the independent variables. These

were sensory modality, short-term memory and constant weight.

Sensory Modality. Two conditions of sensory input were chosen as being relevant to performance of perceptual motor skills.

1. Kinesthetic input: Subjects wore safety goggles with an opaque shield so that they relied for information relating to their performance upon kinesthetic cues.

2. Visual input: Subjects did not wear goggles and could observe their own performance.

Short-term Memory. Three conditions were chosen as being relevant to performances of perceptual motor skills.

1. Immediate recall: For this condition the subject was required to recall within three seconds the position in which he left the handle.

2. Delayed recall: For this condition the subject delayed his recall operation for a period of ten seconds.

3. Delayed recall with an interpolated task: For this condition the subject delayed his recall operation for ten seconds. During this period he was required to perform simple addition exercises.

Constant Weight Load. Three levels of weight were chosen for this factor representative of the weight load that operates in many skilled tasks:

1. Low weight - five pounds.

2. Medium weight - ten pounds.

3. High weight - twenty pounds.

The weight chosen could be applied to a log base 2 graph.

Experimental Design

The independent variables described above were combined in a factorial manner to produce (2 x 3 x 3) 18 experimental conditions. Each subject received every condition four times. The experiment could be described as a treatments by subjects, factorial, fixed factor model replicated four times.

Apparatus

The apparatus consisted of an axle and bearing, rigidly mounted in a timber and Dexion frame. A handle at one end of the axle was used by the subjects to rotate the axle and raise the weights from the floor. The handle was mounted in front of a black painted screen which effectively screened the rest of the apparatus.

To the other end of the axle was attached a second handle used by the experimenter to reposition the subject's handle. A pointer fixed to the axle and a circular scale graduated in degrees enabled the experimenter to measure the angular position of the subject's handle.

From the axle was suspended a chain to which the weights used in the experiment could be attached. The weights were placed on the chain by a colleague seated beside the apparatus.

Surrounding the axle and mounted in the framework was a split-bar clamp brake device. This brake was operated manually by a lever situated conveniently at the rear of the apparatus. The brake operated effectively after a half turn of the lever. A trip switch attached to

the frame was operated by the lever arm of the brake so that the brake and signal to stop operated simultaneously.

The sound signal was produced by a pure tone generator with a sound amplifier and a four inch speaker. This apparatus was placed on an adjacent table.

Behind the subject stood a table on which the addition exercise sheets were laid out. Also on the table were a pair of ski goggles effectively blacked out for use by the subject for all kinesthetic trials.

Error Scale

The error scale was a metal disc graduated in degrees and mounted on the rear of the apparatus. The disc was twelve inches in diameter. The scale was divided into four quadrants to aid in the random treatment of positioning the subject's handle.

Dependent Variable

The dependent variable was obtained by calculating the difference between the trial reading and the recall reading on the circular scale. The difference was termed error. The measurements were read in degrees and recorded to the nearest degree. The measurements were recorded in absolute terms only.

Testing Procedure

1. The appropriate weight was attached to the apparatus.

2. A signal from the tone generator was given.

3. At a predetermined sector of the error scale the signal to stop turning the handle was sounded. Simultaneously with the signal the brake to hold the axle and scale pointer in position was applied.

4. The measurement on the scale was recorded.

5. The weight was removed from the apparatus.

6. The handle was repositioned.

7. The appropriate command to indicate the short-term memory condition was spoken.

8. Procedure at this point depended upon the command given.

I. For the command, "Recall!":

(a) The subject reset the handle.

(b) The measurement on the scale was recorded.

II. For the command, "Delay!":

(a) After a ten second delay as measured by a sweep hand of a wrist watch the experimenter gave the signal "Recall!"

(b) The subject reset the handle.

(c) The measurement on the scale was recorded.

III. For the command "Addition!":

(a) Subjects turned to the table and began the addition exercises to be found there.

(b) After a period of ten seconds the experimenter gave the signal, "Recall!"

(c) The subject reset the handle.

(d) The measurement on the scale was recorded.

<u>Instruction to Subjects</u>

1. On hearing the signal from the tone generator commence turning the handle in a clockwise direction with your right hand.

2. On hearing the signal repeated, stop turning the handle and remove your hand from the handle.

3. Within three seconds you will be given one of the following three commands:

(a) Recall!

(b) Delay!

(c) Addition!

4. You are to respond to these commands in the following ways:

(a) Recall: Take hold of the handle again and attempt to return it to exactly the same position you left it in for the previous trial.

(b) Delay: Wait for the command "Recall!" On hearing that command take hold of the handle again and attempt to return it to exactly the same position as you left it in for the previous trial.

(c) Addition: Turn to the table behind you. Begin the addition exercises to be found there. Write the answers

in the space provided. Continue until you hear the command, "Recall!" On hearing that command turn to the apparatus and attempt to return the handle to exactly the same position you left it in for the previous trial.

5. If you are blindfold when given the command "Addition!" turn to the table and push the goggles up onto your forehead. When you receive the command, "Recall!" replace the goggles over your eyes before you turn back to the handle.

Treatment of Results

1. From the error score for all subjects for all tests a mean error score for each of the eighteen conditions was obtained.

2. A three factor analysis of variance was applied to these scores to obtain F ratios.

3. A Duncan's New Range Multiple Test for the significance of difference on means was applied to significant F values.

4. To test for variation in performance between subjects or for any variation of a subject between repetitions a five way analysis of variance was run, incorporating these two factors with the three independent variables.

5. The $\alpha = .01$ level of confidence was accepted for all hypotheses.

CHAPTER IV

ANALYSIS

Hypothesis

The hypotheses were formulated following a review of relevant literature as presented in Chapter II. With replacement accuracy as the criterion the hypotheses may be stated:

$H_1 : V > K$ (for immediate recall and delayed recall conditions of short-term memory)

$H_2 : K > V$ (for delayed recall plus interpolated task condition of short-term memory)

$H_3 : I = D$

$H_4 : I = D > D + I\ T$

$H_5 : Lo = M = Hi$

where

V = visual modality

K = kinesthetic modality

I = immediate recall

D = delayed recall

D + IT = delayed recall plus interpolated task

Lo = low weight

M = medium weight

Hi = high weight

The first hypothesis for the immediate recall and delayed recall conditions of short-term memory only was formulated from evidence contained in the literature (1,6,29).

The second hypothesis was formulated principally on the evidence of Posner and Konick (29). Their study gave results with a marked interaction effect when a delayed recall plus interpolated task condition was included.

Literature relating to the third hypothesis was found to give conflicting evidence. Although some studies found a linear relationship between the amount of forgetting and delay, others found forgetting was rather constant for some time after presentation of the material to be remembered. Other authors, notably McLane and Hoag (22) found recall followed an inconsistent pattern and was in fact better after a 20 seconds delay than after no delay. The studies do differ in that each tends to be specific in relation to the material used, its method of presentation and recall, and other administrative details. Apparently these factors could be of importance in the conflicting evidence available on immediate recall and delayed recall. In view of these facts and because of the time difference between the two conditions (10 seconds) was so brief, the third hypothesis was formulated as a null hypothesis.

The fourth hypothesis was formulated on evidence from several studies (9,10,16,19,24), all in agreement with the fact that there is a direct relationship between the amount of information in the interpolated task and the amount of forgetting that takes place.

In the absence of any directly related studies, the fifth hypothesis, regarding the information available through the use of different weights in skilled performance, was formulated as a null hypothesis.

Results

All relevant information relating to the tests was placed on IBM data cards, verified and submitted for computation in accordance with the input directions specified in an SSP routine for use on an IBM 360/57 computer.

The means of the 18 experimental conditions are presented in Table I. Each mean is calculated from 36 trials for each condition giving a total of 648 readings for the experiment.

The means for each level of the main effects are presented in Table II. For the short-term memory and weight factors each mean was determined from 216 trials for each level. For the sensory modality factor each mean was determined from 324 trials for each level.

A three way analysis of variance was performed on the main effects. The results are found in Table III.

A statistical significance was found between the three levels of the short-term memory factor. The resulting F ratio was 13.4076 ($p < .01$). A statistical significance was also found between the two levels of the sensory modality factor. The resulting F ratio was 24.1262 ($p < .01$). No statistical significance was found between the three levels

TABLE I

MEANS OF 18 EXPERIMENTAL CONDITIONS

Condition	Mean Error	Condition	Mean Error
1	3.3°	10	9.3°
2	3.3°	11	8.4°
3	7.4°	12	20.1°
4	5.1°	13	9.8°
5	3.5°	14	10.4°
6	14.2°	15	13.9°
7	3.0°	16	7.4°
8	2.5°	17	9.0°
9	7.8°	18	10.8°

TABLE II

MEANS FOR EACH LEVEL OF MAIN EFFECTS

Main Effect	Level	Mean Error
Short-term memory	Immediate recall	6.3°
Short-term memory	Delayed recall	6.2°
Short-term memory	Delayed recall + interpolated task	12.4°
Weight	High	6.7°
	Medium	9.5°
	Low	8.6°
Sensory Modality	Visual	5.6°
	Kinesthetic	11.0°

TABLE III

THREE WAY ANALYSIS OF VARIANCE SUMMARY

ALL SCORES

Source	Sum of Squares	df	Mean Squares	F
S.T.M.	5319.0625	2	2659.5312	13.4076**
Wt.	847.2590	2	423.6293	2.1356
S.T.M. x Wt.	427.9257	4	106.9814	.5393
Mod.	4785.6797	1	4785.6797	24.1262**
S.T.M. x Mod.	46.0833	2	23.0416	.1161
Wt. x Mod.	501.9257	2	250.9628	1.2651
S.T.M. x Wt. Mod.	1189.2961	4	297.3239	1.4989
Error	124966.81	630	198.3600	

CRITICAL F VALUES

df	.05	.01	.001
2,630	3.01	4.64	6.97
4,630	2.39	3.35	4.67
1.630	3.86	6.68	10.95

**Significant at .01 level

LEGEND

S.T.M. = Short-term memory

Wt. = Weight

Mod. = Sensory modality

of the weight factor. The resulting F ratio was 2.1356 ($.90 < p < .75$).

A Duncan's New Multiple Range Test was computed on the means of the short-term memory factor to determine between which levels significance existed. For the purpose of validation the same test was applied to the means of the weight factor. The results of these tests are contained in Tables IV and V respectively.

The mean for the delayed recall plus interpolated task condition was significantly different from the means for the immediate recall and delayed recall conditions. (See Table IV). The means for the weight factor do not differ significantly from each other. (See Table V).

No significant F ratios for the interactions between the main effects were found. (See Table III). For diagnostic purposes and to enable comparisons to be made, Figures 1, 2 and 3 depict relationships between the main effects. In Figure 1 the mean error was plotted against visual and kinesthetic short-term memory. In Figures 2 and 3 the mean error was plotted against weight factor sensory modality and weight factor short-term memory respectively. In Figure 4 the mean error was plotted against the three weight levels of the delayed recall plus interpolated task condition. The purpose of including this figure was specifically to determine how scores from the visual and kinesthetic sensory modalities are distributed for these conditions.

TABLE IV

DUNCAN"S NEW MULTIPLE RANGE TEST
APPLIED TO THE DIFFERENCE ON MEANS FOR
THE THREE LEVELS OF SHORT-TERM MEMORY

Means	6.2 D	6.3 I	12.4 D + IT	Shortest Significant R
6.2	-	.1	6.2**	$R_2 = 3.5$
6.3		-	6.1**	$R_3 = 3.7$
12.4			-	

TABLE V

DUNCAN"S NEW MULTIPLE RANGE TEST
APPLIED TO THE DIFFERENCE ON MEANS FOR
THE THREE LEVELS OF THE WEIGHT FACTOR

Means	6.7 Hi	8.6 Lo	9.5 M	Shortest Significant R
6.7	-	1.9	2.8	3.5
8.6		-	.9	3.7
9.5			-	

**Significant at the .01 level of confidence

Subjects and Replications

To assist in validation of the experimental design in respect of subjects and replications and for diagnostic purposes, a five way analysis of variance was computed. Relevant excerpts from this analysis including F ratios for the main effects and first order interactions are presented in Table VI.

Using the F ratios obtained from Table VI intercomparisons for subjects and replications were obtained by computing first subjects, then replications against the first order interactions.

The resulting F ratios and critical F values ($p < .01$) are presented in Table VII.

Statistical significance was found for the subjects versus subjects by sensory modality interaction. The resulting F ratio was 5.4985 ($p < .05$).

Discussion

From three way analysis of variance (Table III) a significant difference for the two levels of the sensory modality factor was found to exist. The mean error for the immediate recall and delayed recall conditions for kinesthetic sensory modality were 8.8° and 9.3° respectively. The mean error for the immediate recall and delayed recall conditions for visual sensory modality were 3.8° and 3.1° respectively. This information was depicted graphically in Figure 1.

The first hypothesis that accuracy of recall is better for the

TABLE VI

EXCERPTS FROM FIVE WAY ANALYSIS OF VARIANCE
SHOWING F RATIOS FOR MAIN EFFECTS AND
FIRST ORDER INTERACTIONS

Source	Sum of Squares	df	Mean Squares	F ratios
S	5572.4414	8	696.5551	3.7774
Reps	300.3872	3	100.1290	.5430
Reps x S	3907.0945	24	162.7955	.8828
S.T.M. x Reps	620.9226	6	103.4870	.5612
Wt. x Reps	634.9135	6	105.8189	.5738
S.M. x Reps	352.7082	3	117.5694	.6375
S.T.M. x S	5328.8477	16	333.0529	1.8061
Wt. x S	4347.2383	16	271.7023	1.4734
S.M. x S	1013.4443	8	126.6805	.6870
Error	17702.1950	96	184.3978	

LEGEND

S = Subjects

S.T.M. = Short-term memory

S.M. = Sensory modality

Wt. = Weight

Reps. = Replications

TABLE VII

INTERCOMPARISONS FOR SUBJECTS AND REPLICATIONS

Source	df	Calculated F	Critical F
S vs S x Reps	8,24	4.2787**	3.36
S vs S x Wt	8,16	2.5636	3.89
S vs S x S.T.M.	8,16	2.0914	3.89
S vs S x S.M.	8,8	5.4985*	6.03
Reps vs S x Reps	3,24	.6151	4.72
Reps vs Wt. x Reps	3,6	.9467	9.78
Reps vs S.T.M. x Reps	3,6	.9675	9.78
Reps vs S.M. x Reps	3,3	.8516	29.46

** Significant at the .01 level of confidence
* Significant at the .05 level of confidence

LEGEND

S = Subjects

S.M. = Sensory modality

S.T.M. = Short-term memory

Wt. = Weight

Reps. = Replications

visual sensory modality than for the kinesthetic sensory modality for the immediate recall and delayed recall conditions of short-term memory was therefore substantiated.

The second hypothesis that the kinesthetic sensory modality would give greater recall accuracy than the visual sensory modality for the delayed plus interpolated task condition of short-term memory was not substantiated. The mean error for the visual task was 9.8° and for the kinesthetic task 14.8°. The scores are depicted graphically in Figure 1.

Both Broadbent (8) and Posner and Konick (30) claim that the interpolation of an unrelated task between the trial and recall of a task affects visually stored information more than it affects kinesthetically stored information. They suggest this occurs because of a difference in the way visual and kinesthetic information is processed by the central processing mechanism. If visually stored information requires the attention of the central processing mechanism to a greater degree than does the kinesthetically stored information, interference with this mechanism by an interpolated task will cause more interference to the visually stored information than to the kinesthetically stored information.

The fact that this experiment does not support these views could be due to the difficulty of the interpolated task and the length of the delay. The interpolated task used was of sufficient difficulty to cause forgetting, but the amount for each sensory modality was similar. A relatively simple interpolated task was chosen, because the

experiment by Wilberg (36) had shown that an interpolated task of great difficulty caused subjects to forget completely. But the interpolated task used in this experiment may not have been sufficiently difficult to cause the steep rise in errors for the visual tasks, that would be necessary if visual errors were to exceed kinesthetic errors. In addition this experiment used a delay of 10 seconds whereas Posner (28) used delays of up to one minute.

A significant difference exists for the three levels of short-term memory, (See Table III), but the difference does not exist between the immediate recall condition and the delayed recall condition. (See Table IV). This data substantiates the third hypothesis that there is no significant difference in recall accuracy for the immediate recall and delayed recall conditions of short-term memory. Just how similar were the results is evidenced by the difference of only .1° in the mean errors for the two conditions.

Broadbent (8:241) stated that for visual and verbal tasks most forgetting takes place in the first 3 seconds. If this is so, the point must be borne in mind when comparing the error scores for the immediate recall and delayed recall conditions of short-term memory in this experiment, for the immediate recall condition was defined as recall within a period of three seconds. In actual practice it took 3 seconds to reposition the handle and issue the command to recall. This limitation in the administration of the test may have been a factor in obtaining scores so similar.

The fourth hypothesis that for short-term memory the immediate recall condition and the delayed recall condition would give greater accuracy of recall than the delayed recall plus interpolated recall condition was substantiated. (See Table IV). Although the interpolated task was relatively simple it did cause severe interference. (See Figure 1).

There was no significant difference in replacement accuracy for the three levels of the weight factor. (See Table III). This conclusion was supported by the information contained in Duncan's New Multiple Range Test for the difference on means for the three levels of the weight factor. (See Table V). This evidence substantiates hypothesis five that there is no difference in recall accuracy for the three levels of the weight factor. Information relevant to this is depicted graphically in Figures 2 and 3. Figure 2 depicts a fairly constant increase in error for each weight level for information stored kinesthetically as against information stored visually. Figure 3 depicts a similarity in the effect of short-term memory factors upon the three levels of weight. While neither the graph of low weight in Figure 2, nor the graph of high weight in Figure 3 are of significance in themselves, when compared, they do suggest that perhaps under certain conditions weight may be a factor in recall accuracy. The conditions alluded to were for the visual and kinesthetic sensory modalities under the delayed recall plus interpolated task condition of short-term memory. This information is depicted graphically in Figure 4. From this figure

FIGURE 1

MEAN ERROR vs VISUAL AND KINESTHETIC

SHORT-TERM MEMORY

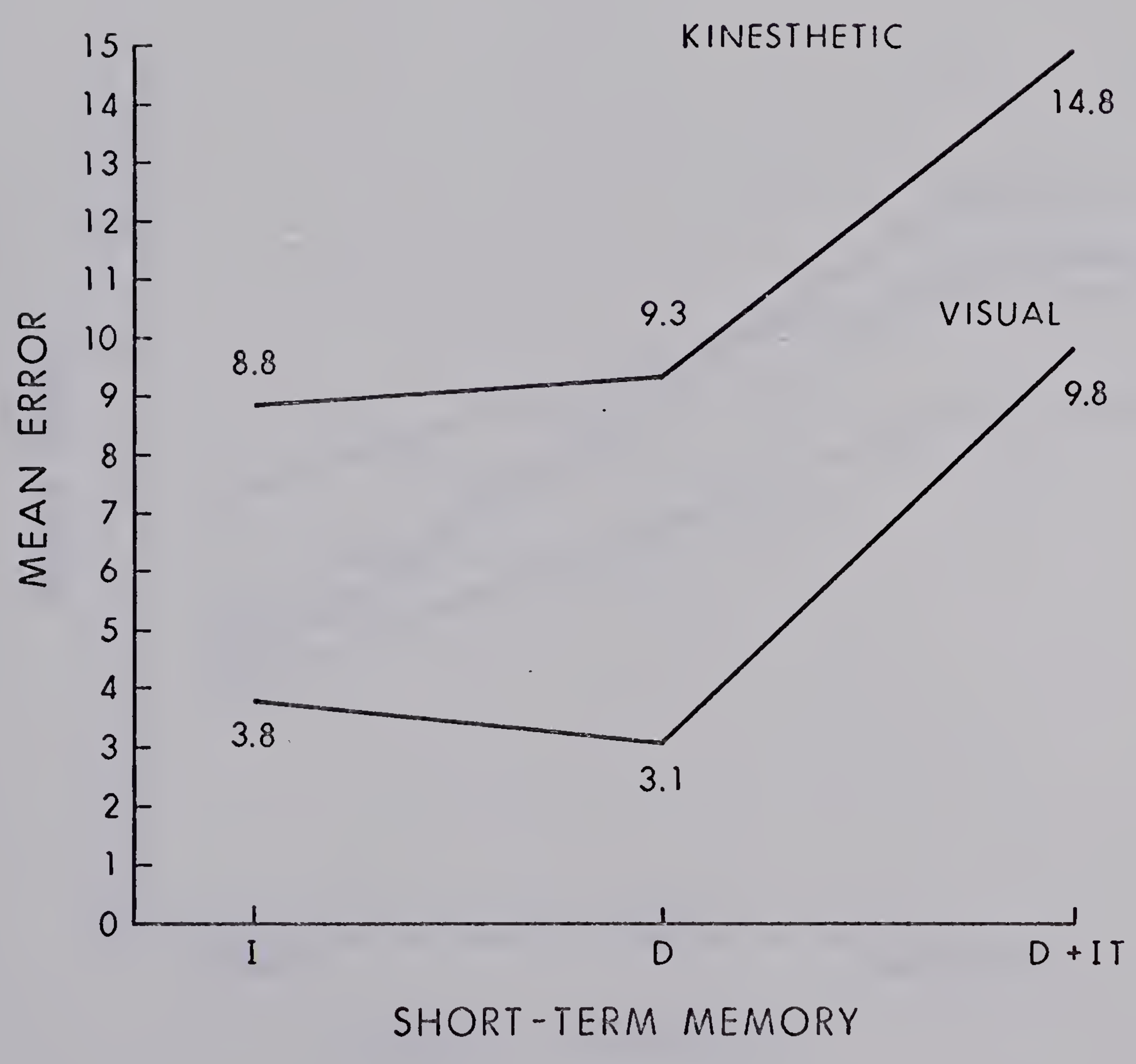


FIGURE 2

MEAN ERROR Vs WEIGHT FACTOR SENSORY MODALITY

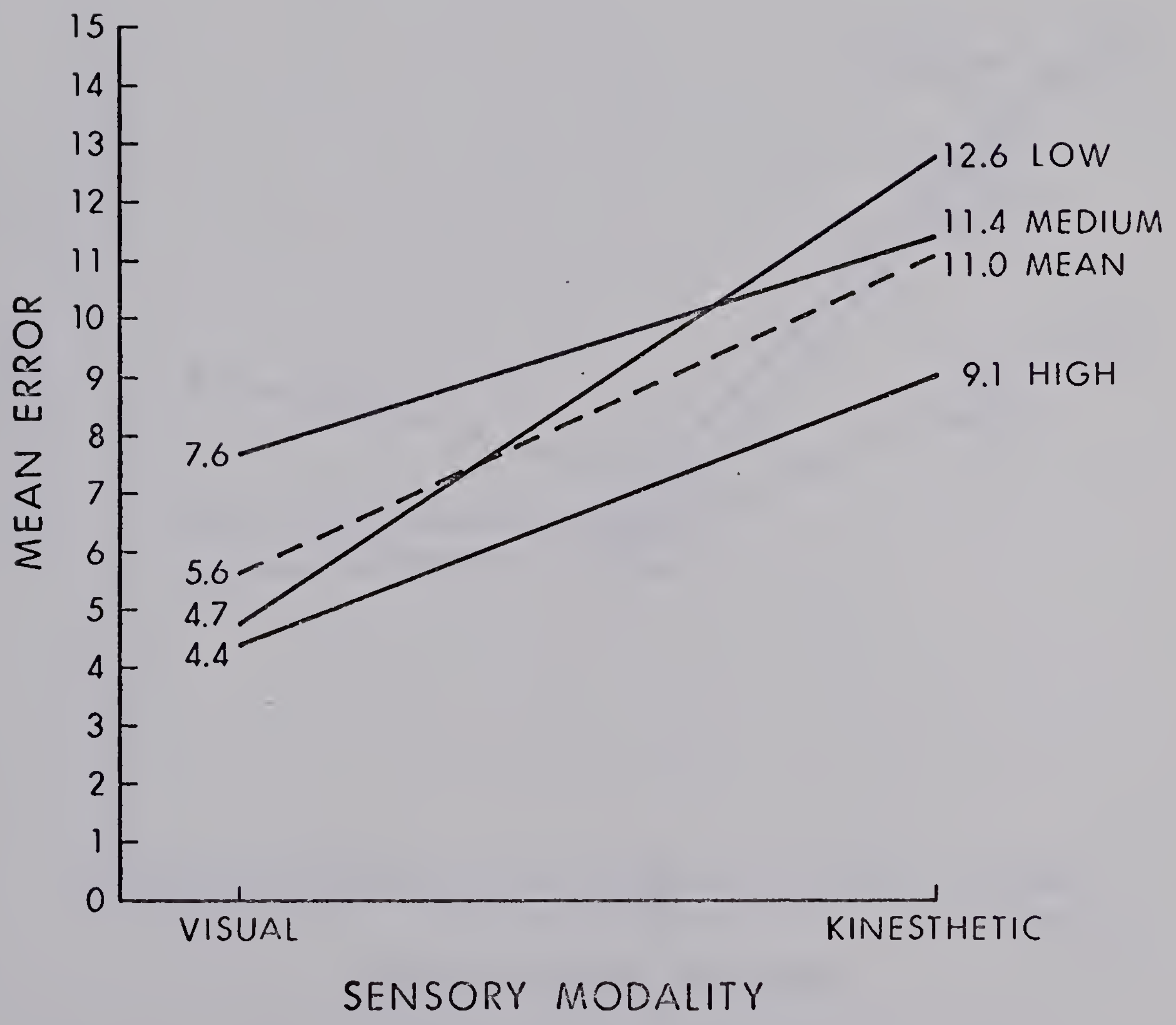


FIGURE 3

MEAN ERROR Vs WEIGHT FACTOR

SHORT-TERM MEMORY

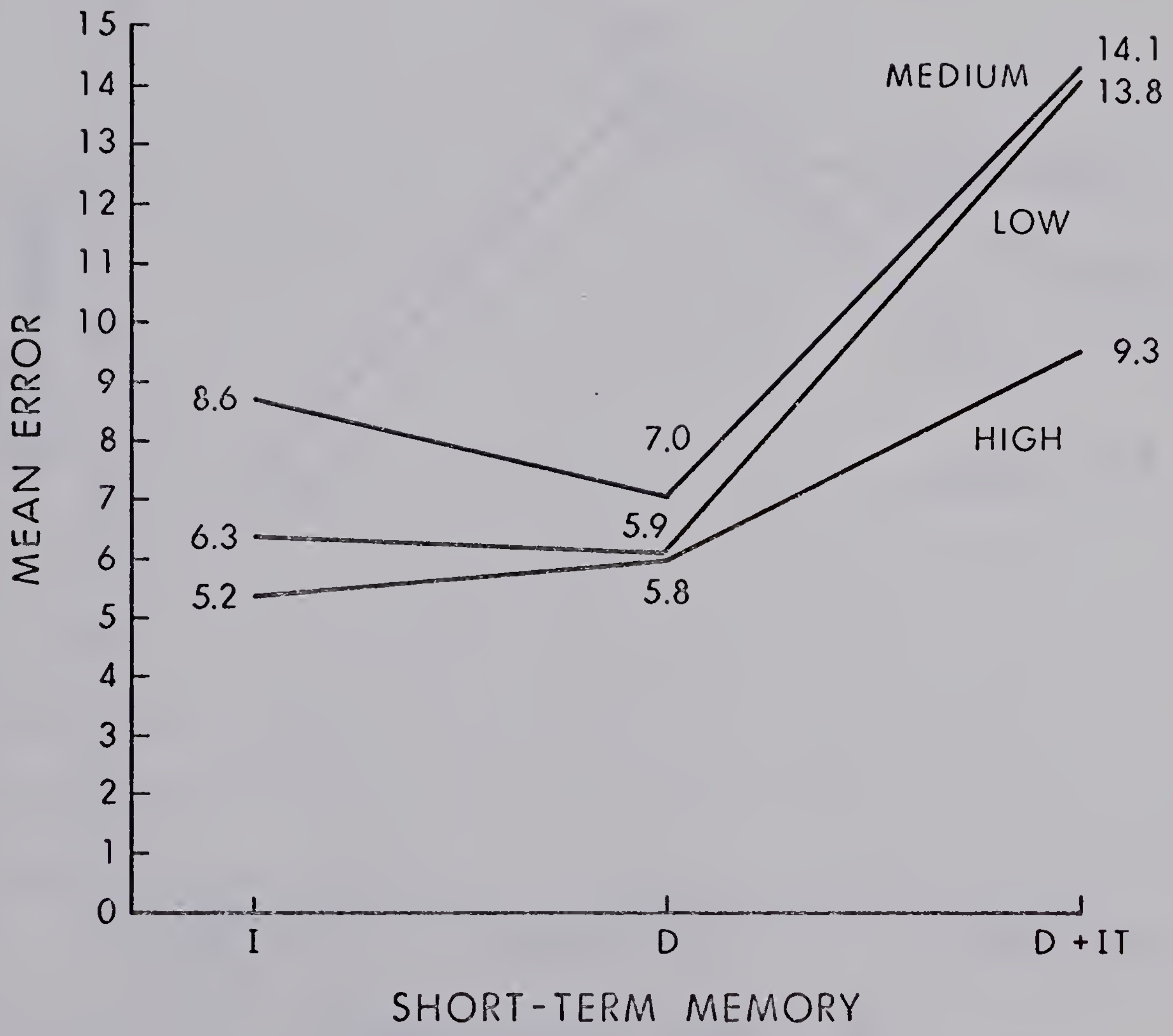
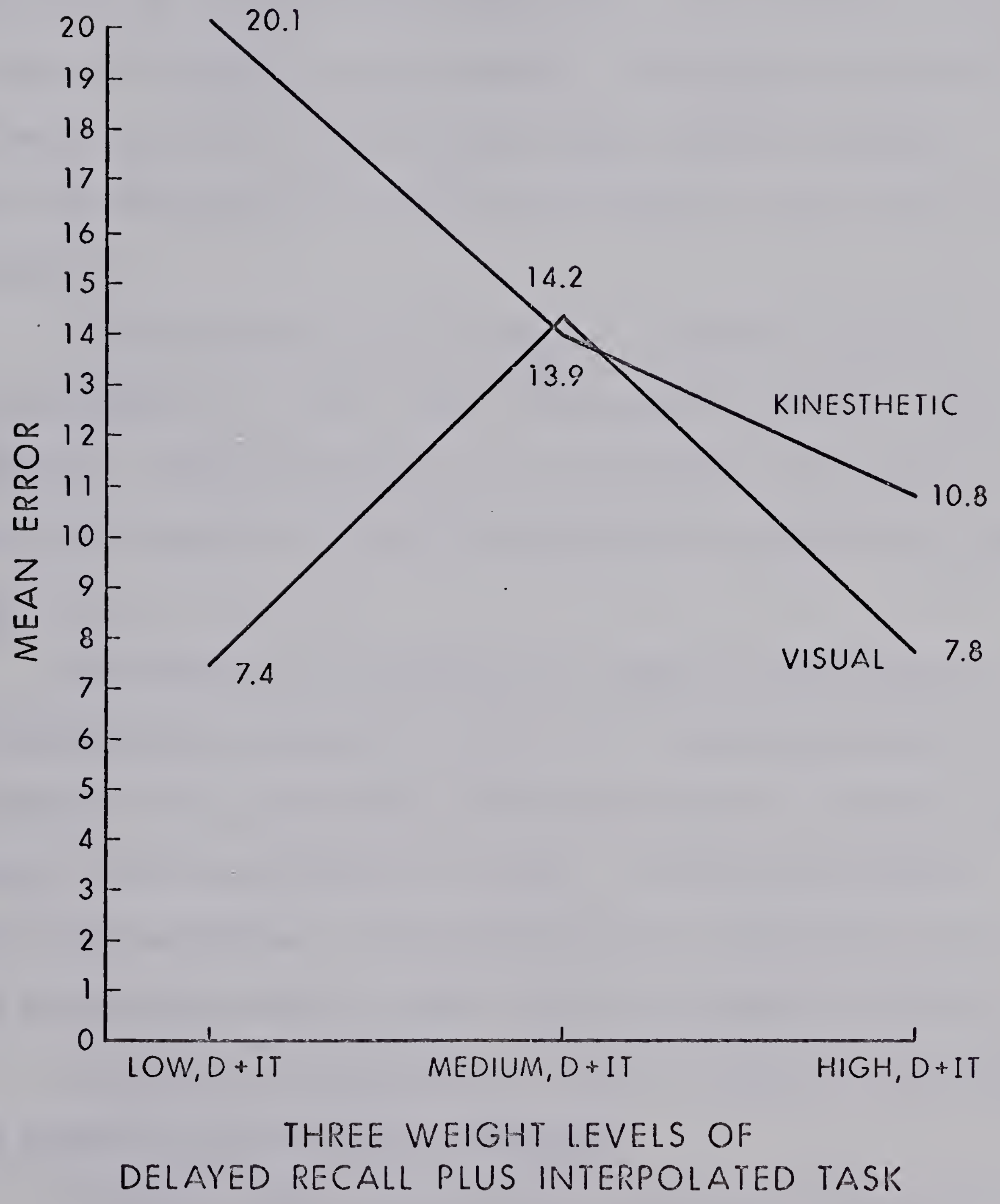


FIGURE 4

MEAN ERROR Vs THREE WEIGHT LEVELS OF

DELAYED RECALL PLUS INTERPOLATED TASK



the discrepancy between visual and kinesthetic accuracy for the low weight and delayed recall plus interpolated task condition of short-term memory can be observed.

From Figure 4 a linear relationship appeared to exist between errors and the log of the weights used. (The intervals along the X axis correspond to a log of weight). Although the evidence was by no means conclusive that increased weight caused a decrease in errors, the implications for skilled performance of such a fact are of importance.

Intuitively one would not expect a change in weight to affect performance of a skill when information was visually loaded into memory. Although the graph for visual recall did not seem to support this contention a conclusion should not be based on this data. $F_{2,105} = 1.46, .4 > p > .5$

No statistical significance was found for replications in the intercomparisons reported in Table VII. From these results it was apparent that no significant difference occurred in subjects' performances from one replication to another. Collectively subjects treated each replication in the same manner even though their skill levels were not the same for each of the 18 experimental conditions.

Statistical significance ($p < .01$) was found for the subjects versus subjects by replications interaction.

Evidently there was considerable variation in the way the

subjects performed in comparison with each other during each replication.

Statistical significance ($p < .05$) was also found for the subjects versus subjects by sensory modality interaction. From these results it is clear that the subjects differed from each other in the way they responded to visual and kinesthetic trials.

Therefore it is clear that individual differences existed in the way the subjects performed on this experiment. However the performances of all subjects although varying in extent did not vary in direction. All subjects exhibited the same trends in performance on the independent variables.

FIGURE 5

VIEW OF APPARATUS FROM THE REAR

FIGURE 6

SUBJECT PERFORMING REPLACEMENT ACCURACY TASK

CHAPTER V

SUMMARY AND CONCLUSIONS

Summary

The purpose of this experiment was to investigate the visual kinesthetic short-term memory of a constant weight load. Performance by the subjects on 18 experimental conditions was measured by a replacement accuracy task. Accuracy was measured in degrees. The 18 experimental conditions consisted of all combinations of 3 levels of short-term memory, 3 levels of weight and 2 levels of sensory modality. The 18 experimental conditions were presented to the subjects in random order. Each subject repeated the experiment on 4 separate occasions. Subjects were 9 right dominant male members of the P.E. 218 class of the University of Alberta.

Following a review of the relevant literature the following 5 hypotheses were formulated to aid in the investigation:

1. Replacement accuracy for visual performance is better than for kinesthetic performance for the immediate recall and delayed recall conditions of short-term memory.

2. Replacement accuracy for kinesthetic performance is better than for visual performance for the delayed recall plus interpolated task condition of short-term memory.

3. There is no significant difference in replacement accuracy for the immediate recall and delayed recall conditions of short-term memory.

4. Replacement accuracy for the immediate recall and delayed recall conditions is better than for the delayed recall plus interpolated task condition of short-term memory.

5. There is no significant difference in replacement accuracy for the low, medium and high weight.

Raw data was collated and submitted to three way and five way analyses of variance. Significant F ratios were further analysed by means of a Duncan's New Multiple Range Test.

Conclusions

Skilled performance was significantly better when the information used by the performer was loaded visually, than when it was loaded kinesthetically. This applies even when performance was delayed and interrupted by an interpolated task. Although this latter conclusion was contrary to the conclusion reached by Posner and Konick, the nature or difficulty of the interpolated task used may have given rise to the difference. If this were so an amendment to the Posner and Konick study may be necessary, indicating that the relationship between visual and kinesthetic performance for a delayed recall plus interpolated task condition depends upon the difficulty of the interpolated task. Furthermore kinesthetic performance would only exceed

visual performance when the actual amount of forgetting was considerable. In view of this and the difference in means for the combined weights 5.4°, (Figure 2), which represents a difference of almost 100%, the role of kinesthetic feedback in skilled performance may not be as important as has often been claimed.

Delayed response did not appear to affect the level of skilled performance when compared with immediate response. However this conclusion must be viewed in the light of the limitation of the experiment in regard to immediate recall. Broadbent (8) claims that most forgetting occurs in the first three seconds and in view of the mean error for visual and kinesthetic modalities combined (6.3° for immediate recall and 6.2° for delayed recall), results of this experiment do not refute Broadbent's claim. But the combined means do not present all the picture. For the delayed condition the kinesthetic error (9.3°) was exactly 3 times the error for the visual condition (3.1°), and this size error (.83%) or 3/8" in the position of the handle, was comparatively small. This comparison again emphasises the superiority of visual performance over kinesthetic performance.

The proportionally greater increase in errors for the delayed recall plus interpolated task condition of short-term memory for the visual performance compared with kinesthetic performance supported the previous claim, that the difficulty of the interpolated task determines the relationship between visual and kinesthetic performance for this condition of short-term memory.

The results of this experiment lead to the conclusion that a constant weight load was not used by subjects as an aid to performance in a task of this nature. Wilberg (36) using constant torque and Moyst (20) using constant ballistic load concluded that these factors were not used by subjects as an aid to performance. The constant nature of the load in these experiments may defeat the aims of the investigation. The use of a varying load on resistance may provide the performer with the type of feedback he could use as an aid in performance.

Further Direction

During the course of the experiment the ability of the task to adequately measure replacement accuracy came under doubt. Subjectively, there appeared to be discrepancies in scores obtained, depending upon from which segment of the circle the score was taken.

It may be argued that the nature of the task places the arm of the performer in positions of mechanical advantage and in positions of mechanical disadvantage. Consequently it could be that this factor results in greater or lesser amounts of information being available to the performer under the kinesthetic sensory modality tasks. Assuming this information aids in replacement accuracy, the error score obtained would include a constant error factor due to the position in the circle from which the score was obtained. An experiment to test recall accuracy from different segments of the circle would test this question.

A second question relating to the task arose by virtue of the predisposition of subjects to replace the handle by rotating in a clockwise direction. Only on one occasion out of 648 test trials was this direction reversed. The tendency was most noticeable when the handle was repositioned by the experimenter so that the subject need only move the handle anticlockwise a few degrees to obtain the correct setting. In these cases subjects rotated the handle clockwise to obtain the recall setting. Even when the handle needed to be rotated a few degrees clockwise to obtain the correct setting, subjects tended to rotate the handle a full circle before obtaining the recall setting. On some occasions subjects even rotated the handle twice before stopping at, or close to their previous setting. Accurate recalls by subjects were characterised by a smooth and positive rotation of the handle. Inaccurate recalls were characterised by hesitancy in movements and frequent small adjustments.

An experiment involving recall in the same and in the opposite direction to the original movement, may assist in deciding if the actual repetition of the original movement is an aid in recall.

A third question arising from this study relates to the effect of weight upon visual and kinesthetic replacement accuracy under the condition of delayed recall plus interpolated task.

Figure 4 contains information suggesting that weight was of assistance in aiding recall accuracy for the kinesthetic delayed recall plus interpolated task condition. An experiment designed specifically

to study this question and using a greater range of weights could add to the understanding of information used by performers in skilled activities.

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APPENDICES

APPENDIX A

TESTS FOR RIGHT DOMINANCE

TESTS FOR RIGHT DOMINANCE

The following tests were administered to volunteers for the experiment to ensure that only subjects who were right dominant would be selected.

Leg Test - Volunteers were asked to kick at a small object placed on the floor in front of them.

Arm Tests - Volunteers were asked to sign their names. A second test required the subjects to pick up and turn over a number of coins lying on a table.

Eye Tests - Volunteers were first asked to aim a gun and second to read figures on a card by peering through a small aperture in another card.

For each test a note was made of the side preferred by the volunteer. Only those who showed right preference on all tests where chosen as subjects.

APPENDIX B

INTERPOLATED TASKS

NAME: Karol Szynkowski

15	4	16	3	12	7	14	16	18	15
9	17	6	18	10	16	8	9	5	8
19	11	7	2	15	13	8	7	11	10
3	10	13	19	6	9	18	15	9	17
14	7	17	5	12	11	15	14	7	18
8	12	4	13	8	13	9	11	17	5
13	7	14	6	12	8	10	8	4	9
8	18	5	13	13	16	4	14	13	18
19	5	15	8	16	13	15	12	13	17
5	17	5	14	9	9	6	17	9	6
11	14	13	17	11	6	15	19	12	14
8	12	8	6	17	12	7	4	16	8
16	13	17	12	15	6	18	14	12	9
7	9	4	9	7	17	9	13	15	8
6	17	12	13	7	16	4	18	7	15
5	8	15	5	4	8	14	5	6	2

NAME:

13	8	16	12	13	18	5	20	16	14
14	7	11	4	9	10	17	4	12	8
11	18	3	15	13	15	6	8	14	17
7	5	14	12	9	4	7	16	9	6
18	14	5	14	9	12	3	6	17	4
5	3	7	8	13	8	14	6	7	15
18	14	7	3	14	8	18	15	17	4
3	9	17	14	9	8	6	4	6	8
13	17	14	12	7	14	8	17	13	19
9	8	6	11	16	12	9	4	12	8
18	13	17	14	15	8	9	12	14	9
6	12	5	9	7	14	17	9	3	16
14	5	13	19	12	13	5	17	7	5
7	6	15	3	17	14	8	6	13	18
14	17	9	12	15	14	19	13	18	9
11	8	15	7	12	11	7	4	6	13